

## Status of fission fragment observables measured with the LOHENGRIN spectrometer

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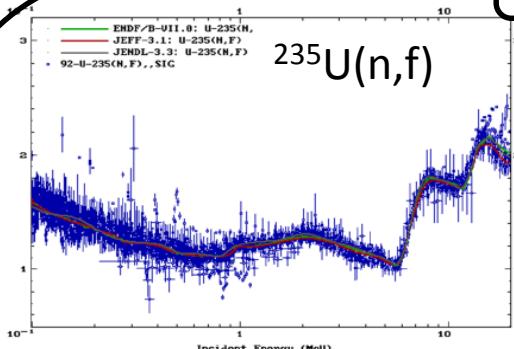
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# 1- Context & logic of ND

## Benchmark reactor/irradiations



NNDC, Brookhaven

Evaluated ND

Database

=

Validated models



Venus, Belgique

Phenomenological / Ab-initio  
Models

TEST

Direct data  
Cross section; yields ; decay data

### *a priori* models

- Level density
- Spin distribution
- Strength Function
- ...

### *Indirect data*

- Measurements on reaction mechanisms
- Nuclear structure data
- Isomeric ratio
- ...

# 1- indirect data : test of models for ND evaluation

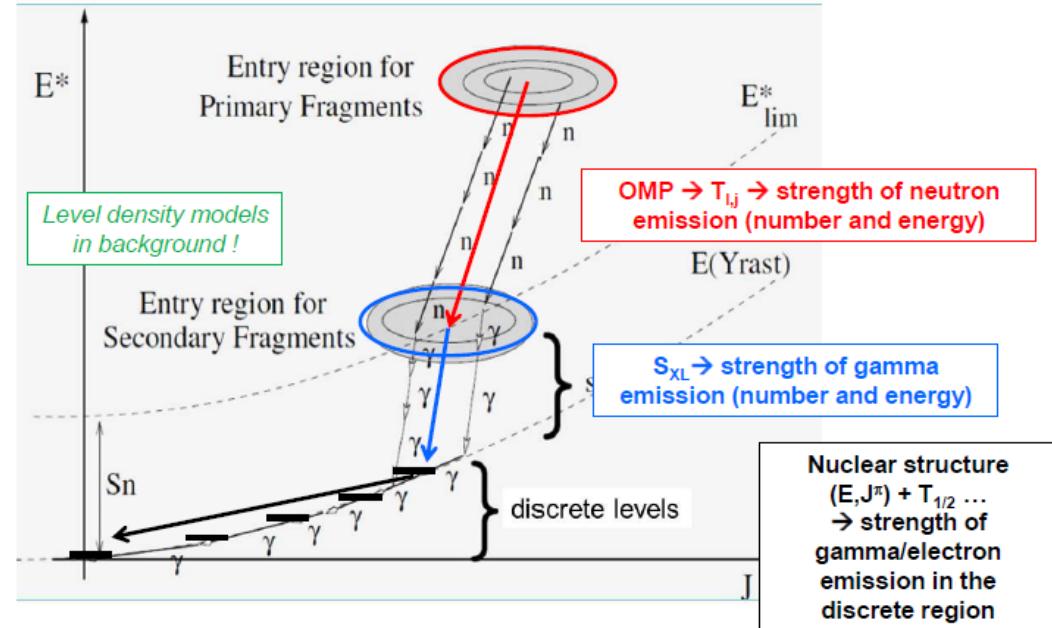
➤ Accurate and absolute data to test the model assumptions in the framework of data evaluation

➤ Theoretical description :

$$Y(A, Z, E^*, J^\pi) = Y(A, Z) \times P(E^*, J^\pi)$$

Symmetric and far asymmetric regions :

- test of the model assumption validity for evaluations



(Z, I) Kinetic energy dependence :

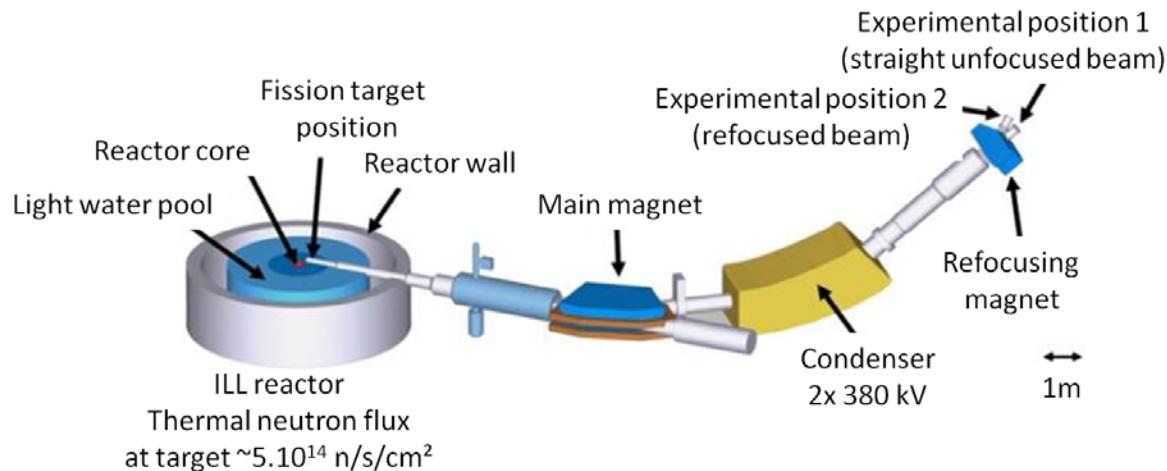
- $P(E^*, J^\pi)$  excitation energy sharing and spin distributions
- modeling prompt particle emission ( $n/\gamma$ ) - cascade – competition ( $n/\gamma$ )
- foreseen material damage/heating in the reactor studies

O.Litaize et al., Workshop CW-2017,  
2nd-6th october 2017, Aix en Provence,  
France.

➤ Observables  $Y(A, Z, E_k, J, \pi) = Y(A) \cdot P(Z|A) \cdot P(E_k|A, Z) \cdot P(IR, n, \gamma|A, Z, E_k)$

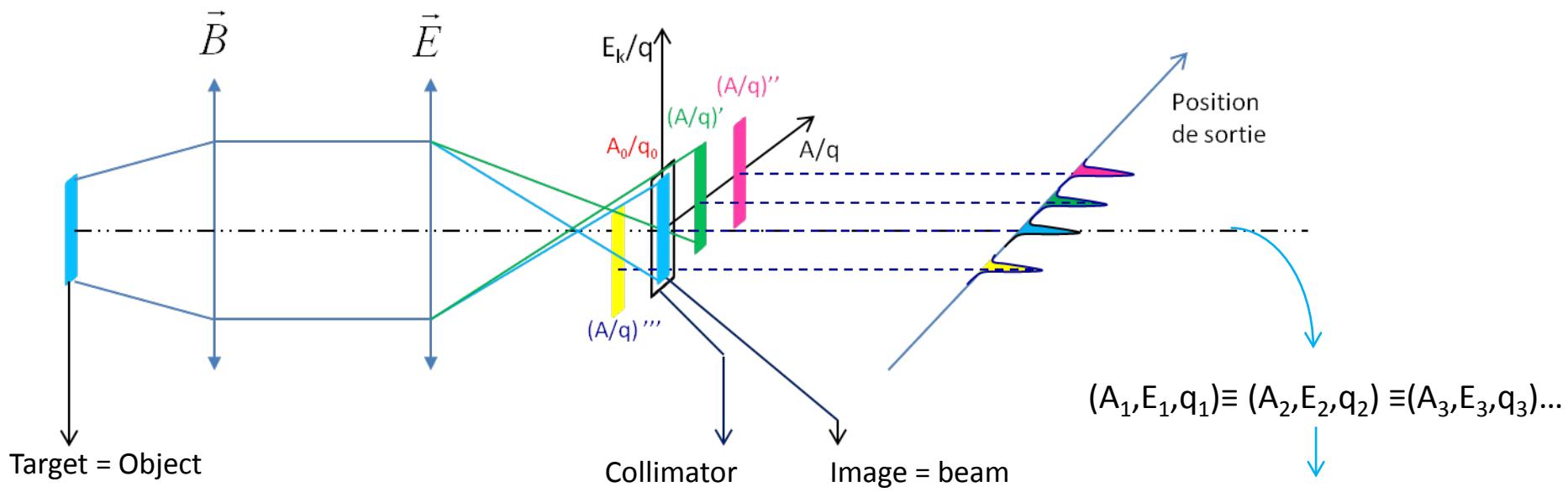
Mass	Charge	Kinetic energy	Isomers	prompt particles
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## 2- Lohengrin spectrometer & methods

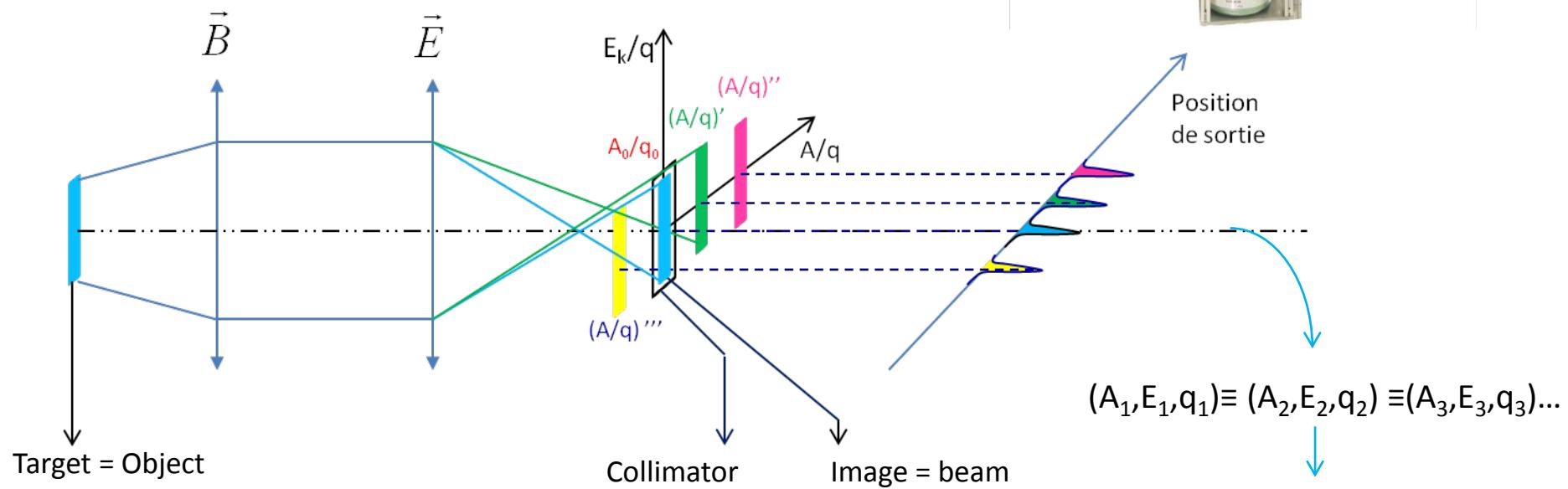
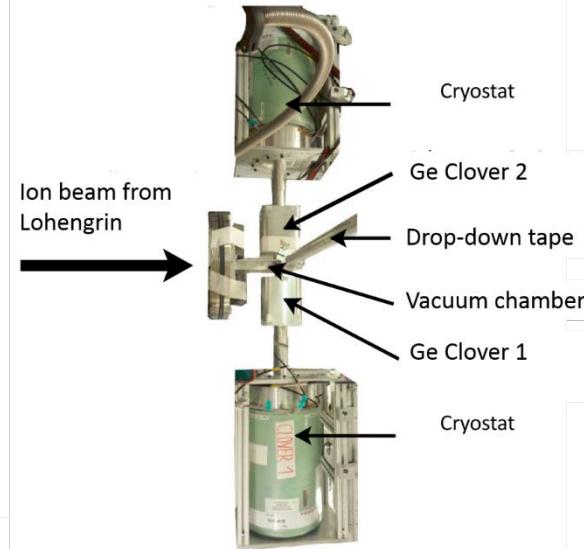
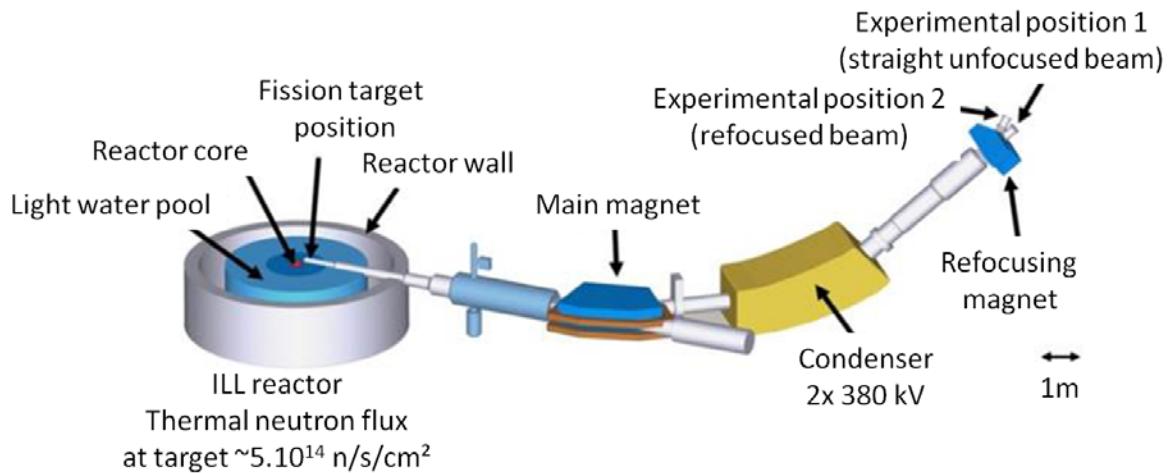


- **Mass identification**  
→ Double ionization chamber with Frisch grid

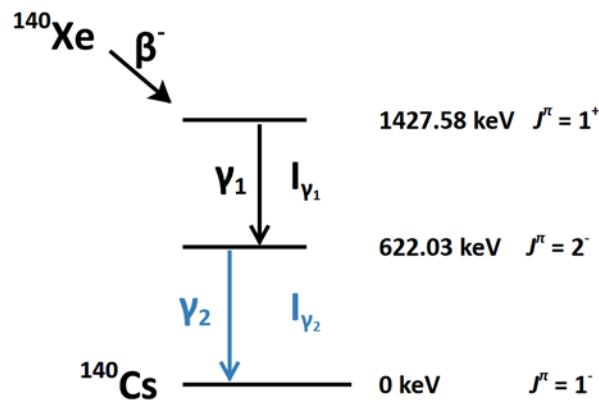
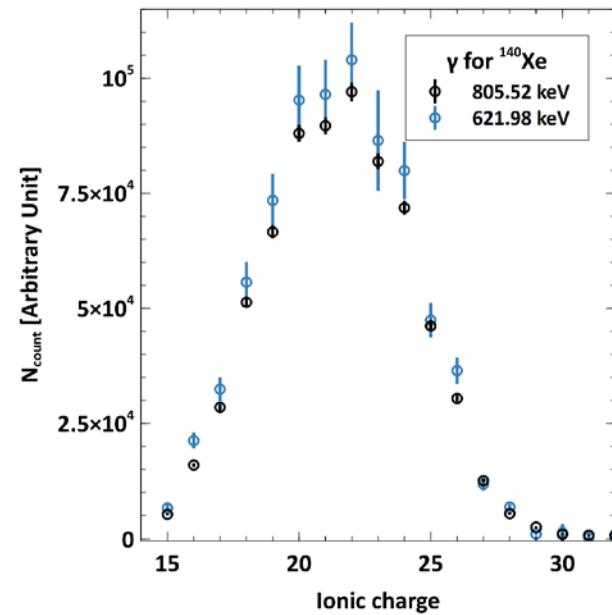
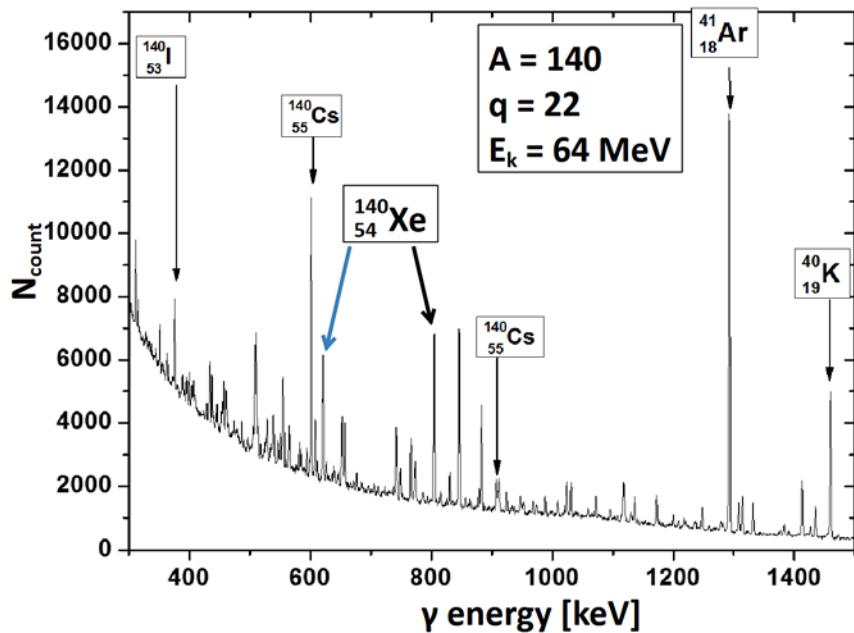
- **Isotope identification**  
→ Ge detectors



## 2- Lohengrin spectrometer & methods



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Distribution en charge ionique pour deux raies  $\gamma$  du  $^{140}\text{Xe}$  (corrigée de l'efficacité du détecteur, de  $I_\gamma$  et de  $f_\gamma$ )

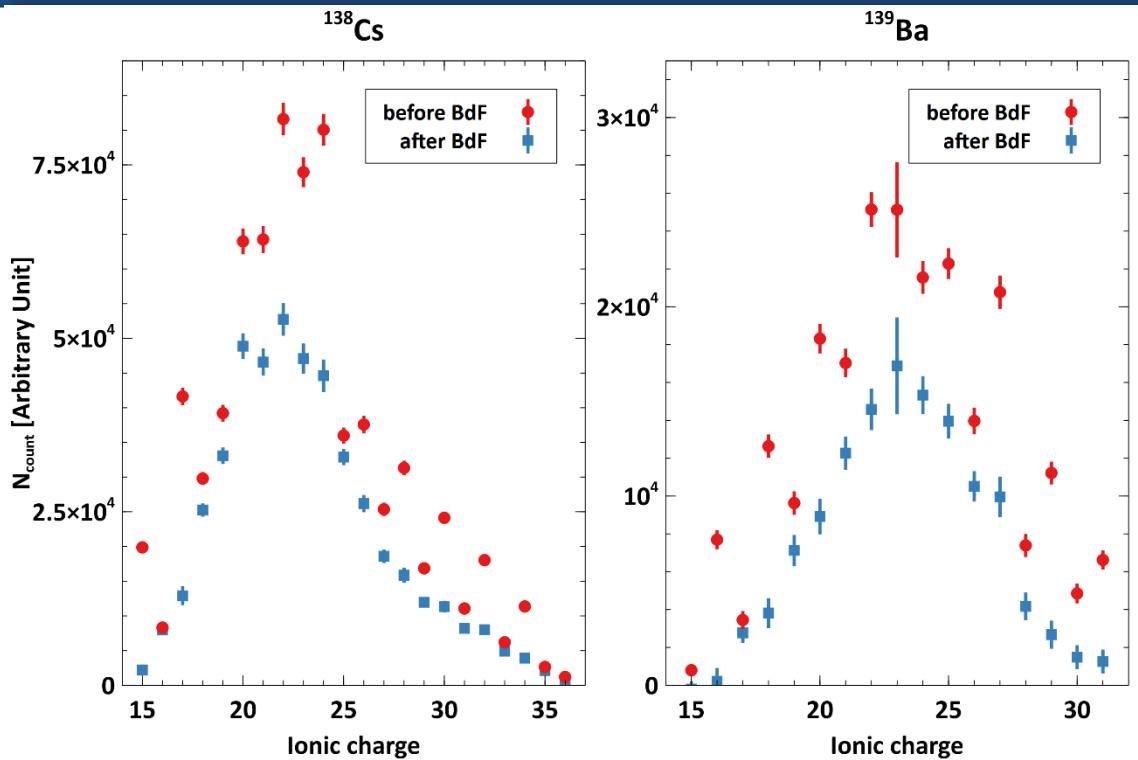
Intensité d'une émission  $\gamma_i$  :  $I_{\gamma_i} = \text{Probabilité d'émettre } \gamma_i$

$$I_{\gamma_i}^{\text{rel}} \cdot I_{\gamma_i}^{\text{norm}}$$

indépendant

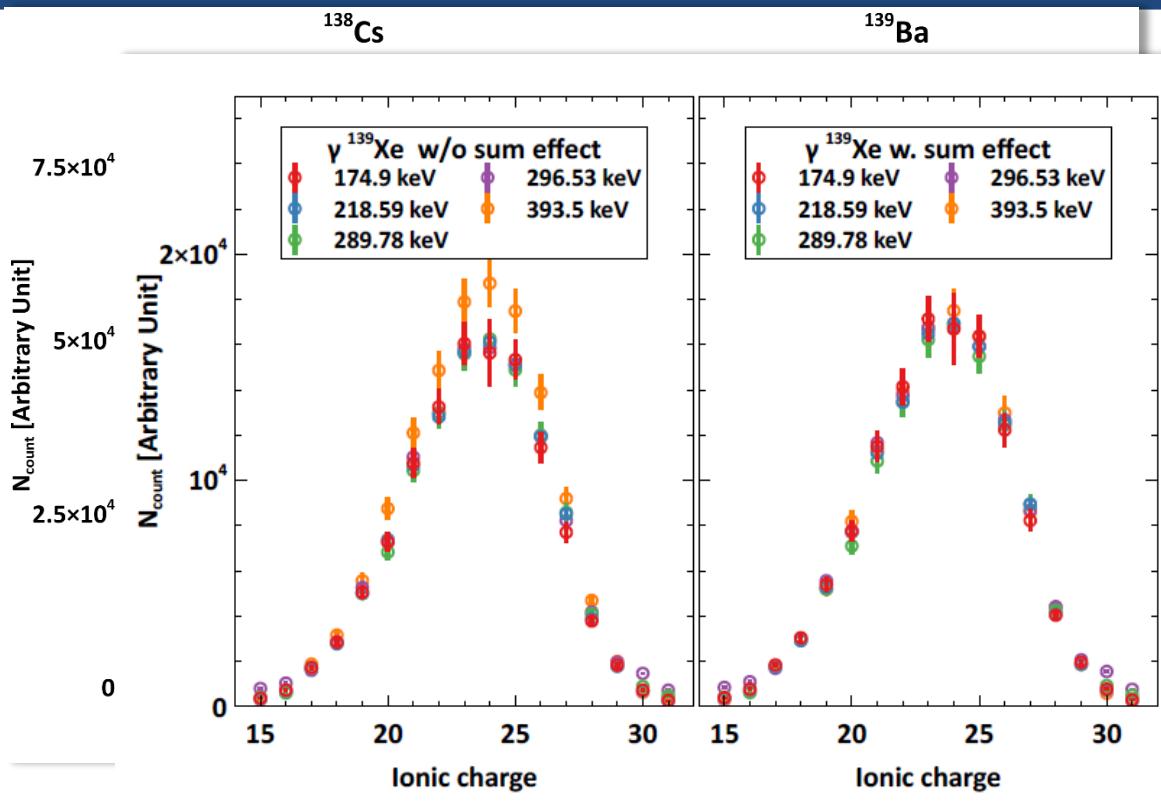
commun aux raies d'un isotope

## 2- Lohengrin spectrometer & methods



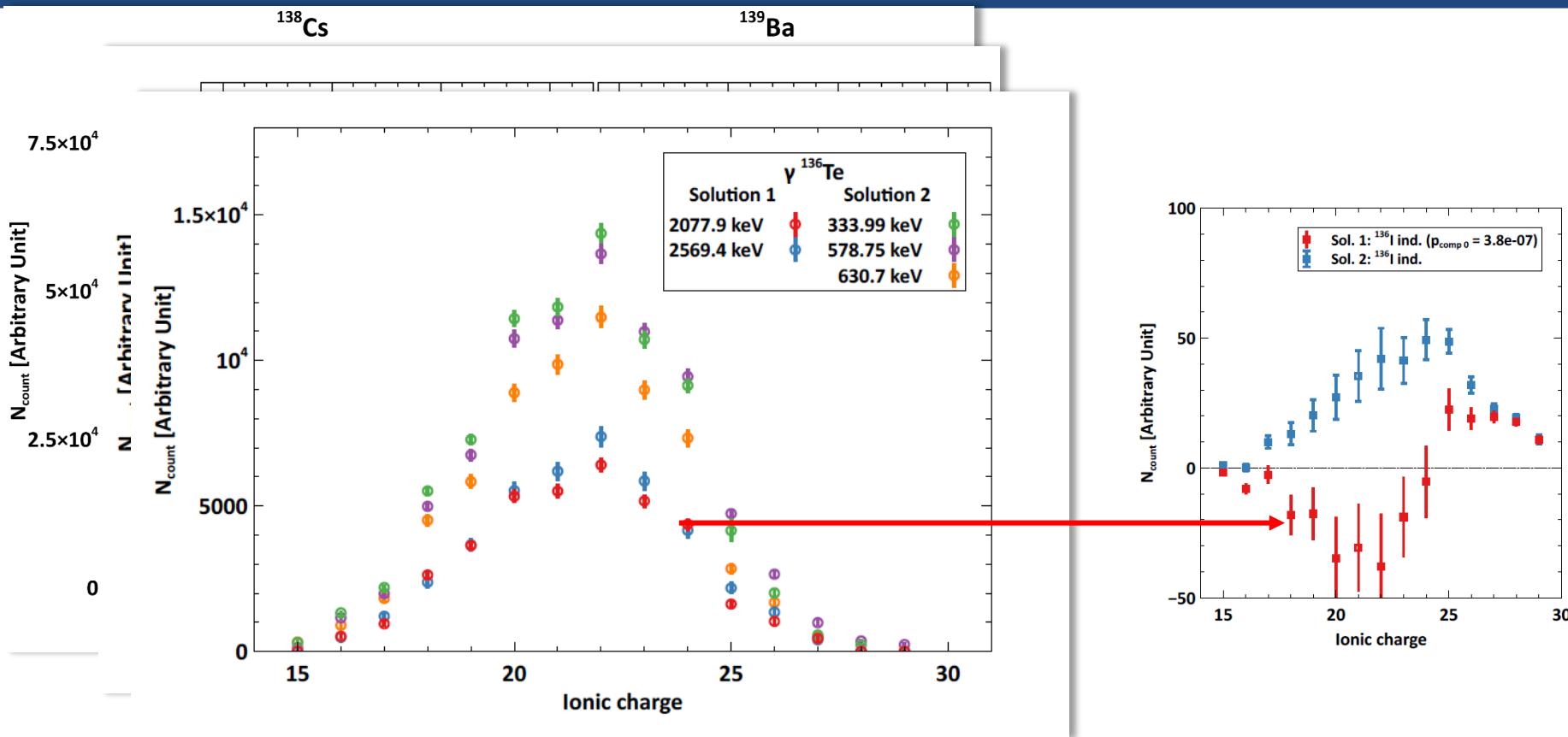
- Long lifetime isotopes : correction of the ions deposited on the frame

## 2- Lohengrin spectrometer & methods



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- Sum effect correction to verify the compatibility of the  $N(q|A,\gamma)$  distribution

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- Long lifetime isotopes : correction of the ions deposited on the frame
- Sum effect correction to verify the compatibility of the  $N(q|A,\gamma)$  distribution
- Do a choice in case of incompatibility → Bateman correction  $\Rightarrow N(q) > 0$

### 3- Direct and indirect nuclear data : $^{241}\text{Pu}(n_{\text{th}}, f)$

Fission observables achievable with the Lohengrin spectrometer

- 1 - Isotopic and isomeric yields
- 2 - Charge polarization
- 3 - Isotopic and Isomeric dependency with the kinetic energy and pairing effect
- 4 - ns converted isomeric ratios

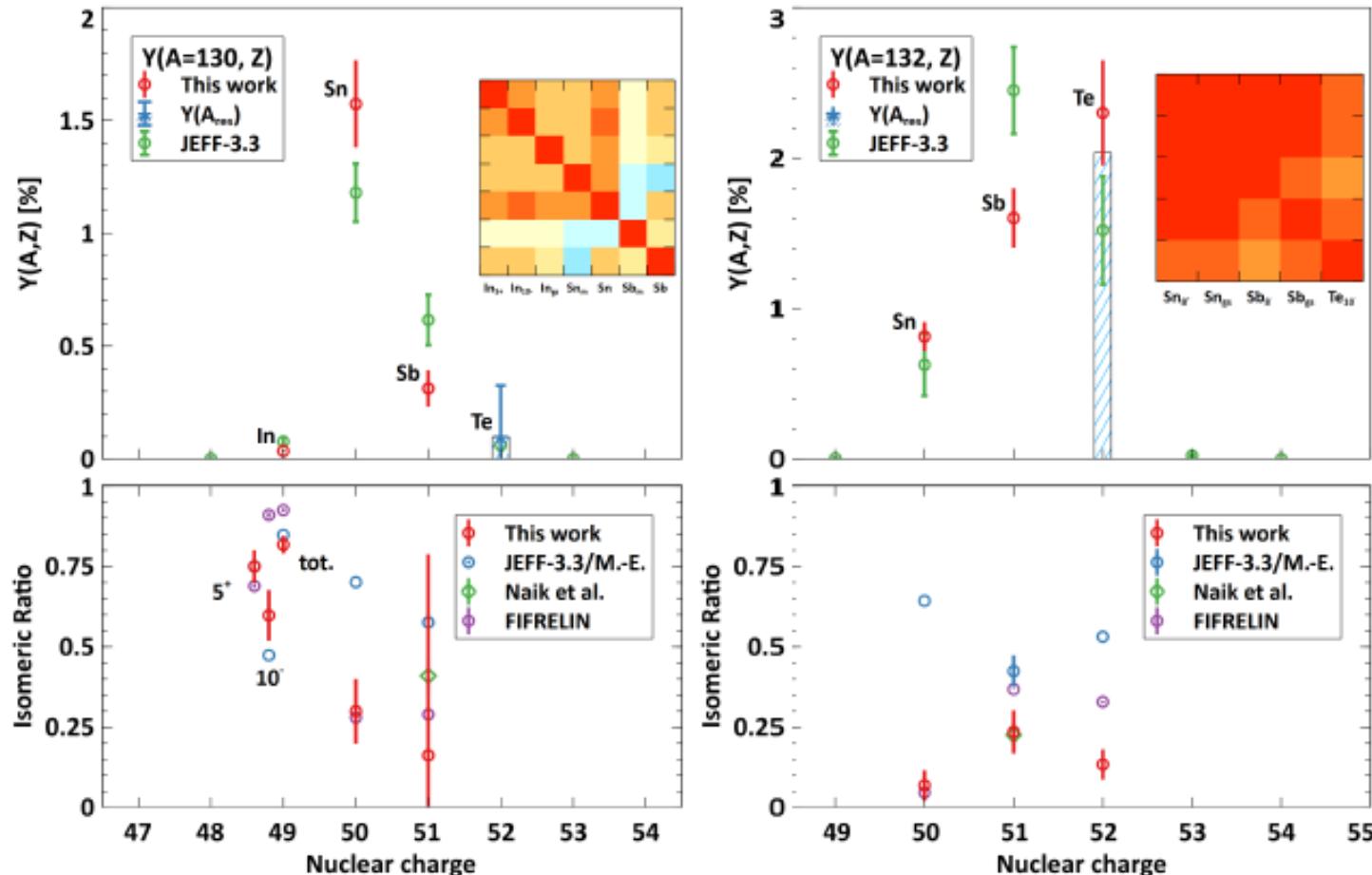
*S. Julien-Laferrière PhD Thesis 2018*

### 3.1- Direct data : $^{241}\text{Pu}(n_{\text{th}}, f)$ Isotopic & Isomeric yields

S. Julien-Laferrière PhD Thesis 2018

Complementarity between mass and isotopic measurement

Large range of isomers from ns to ms life-time → library of test of spin distribution

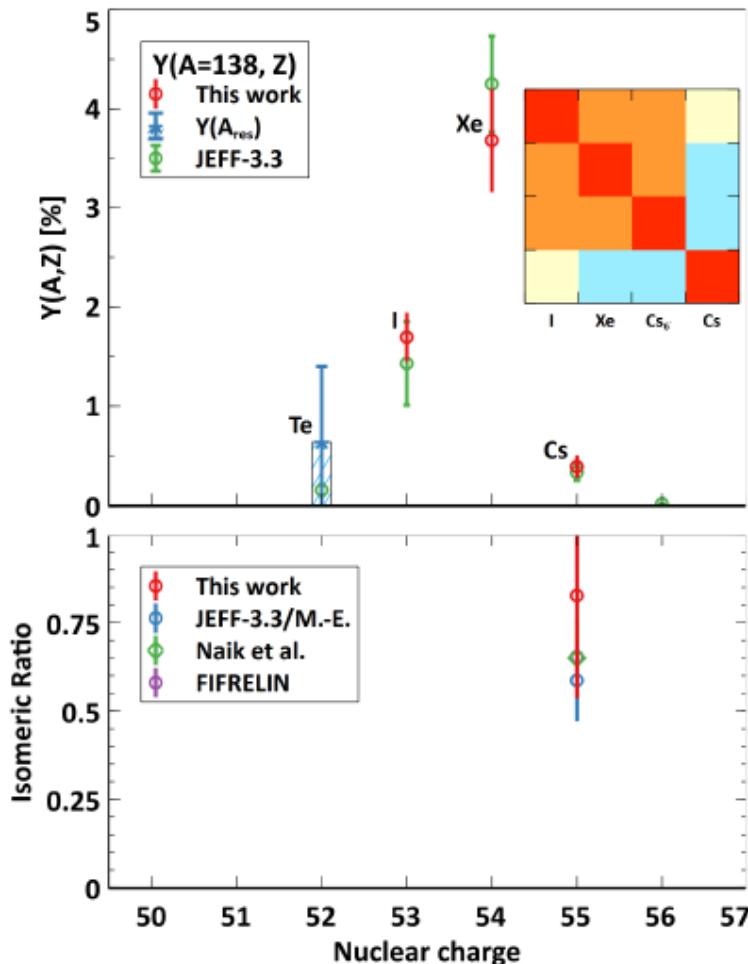
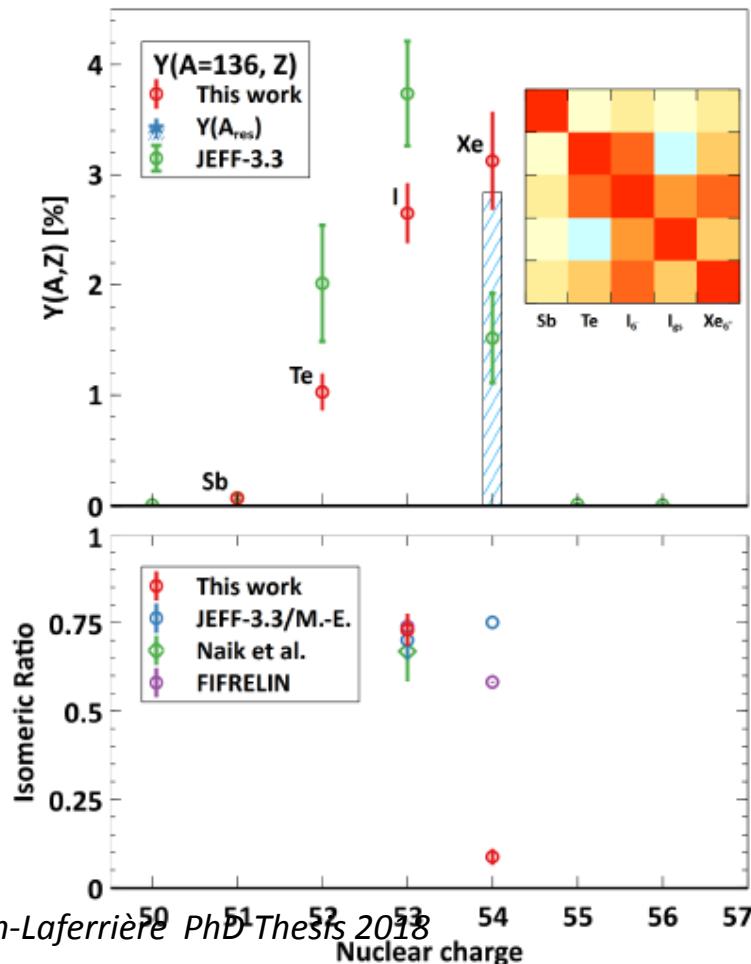


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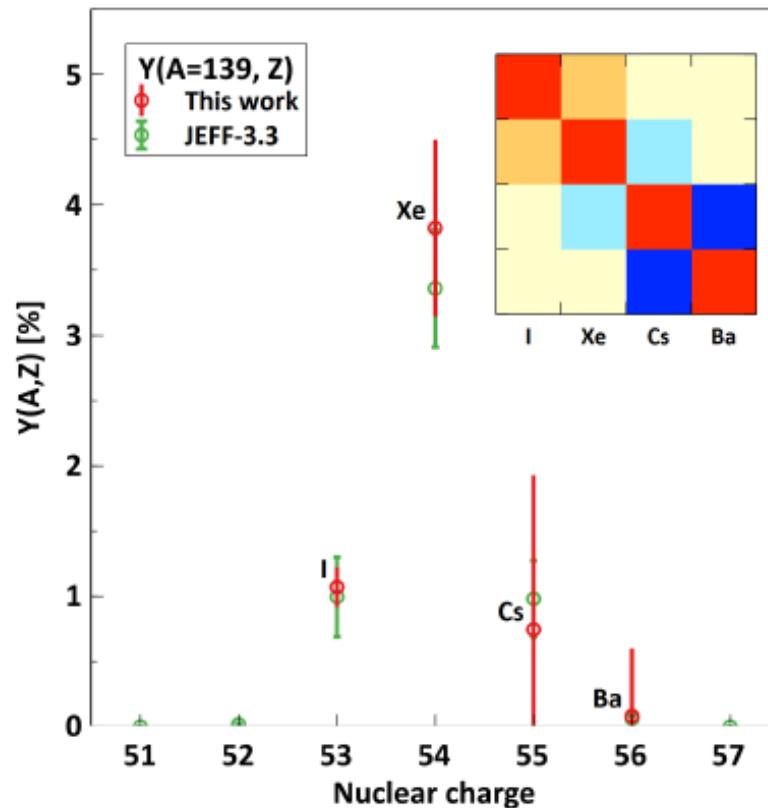
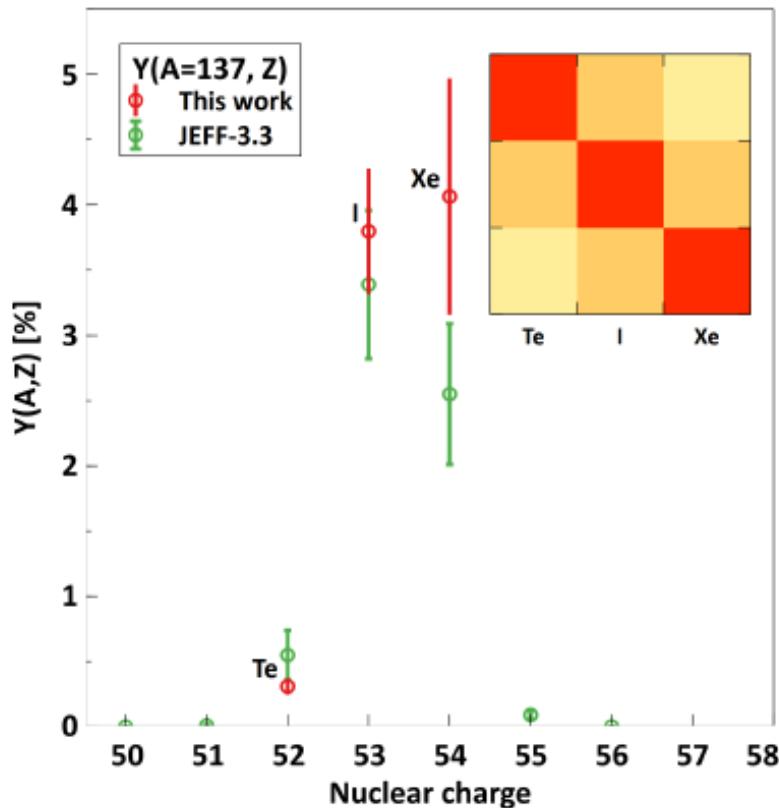


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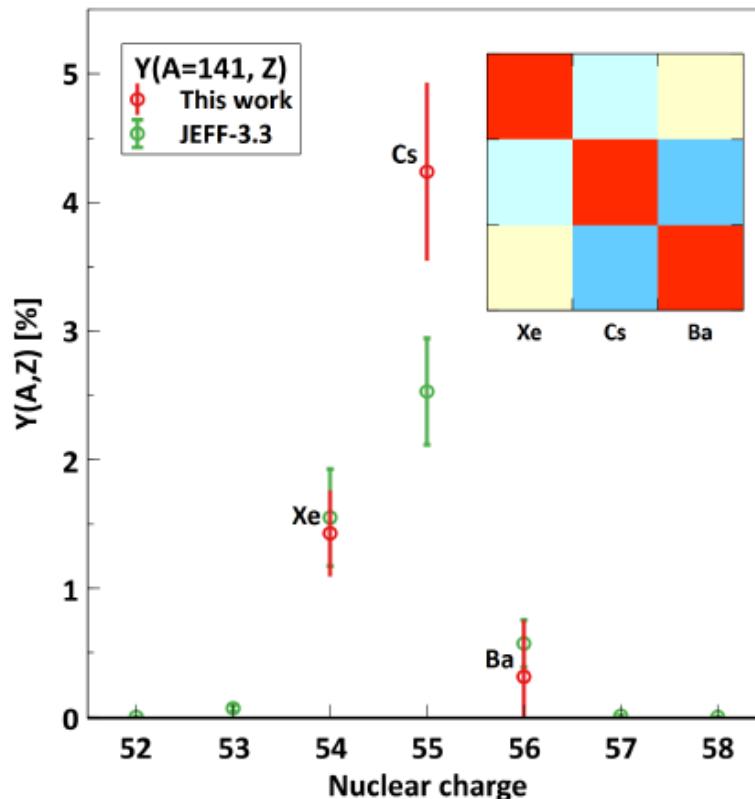
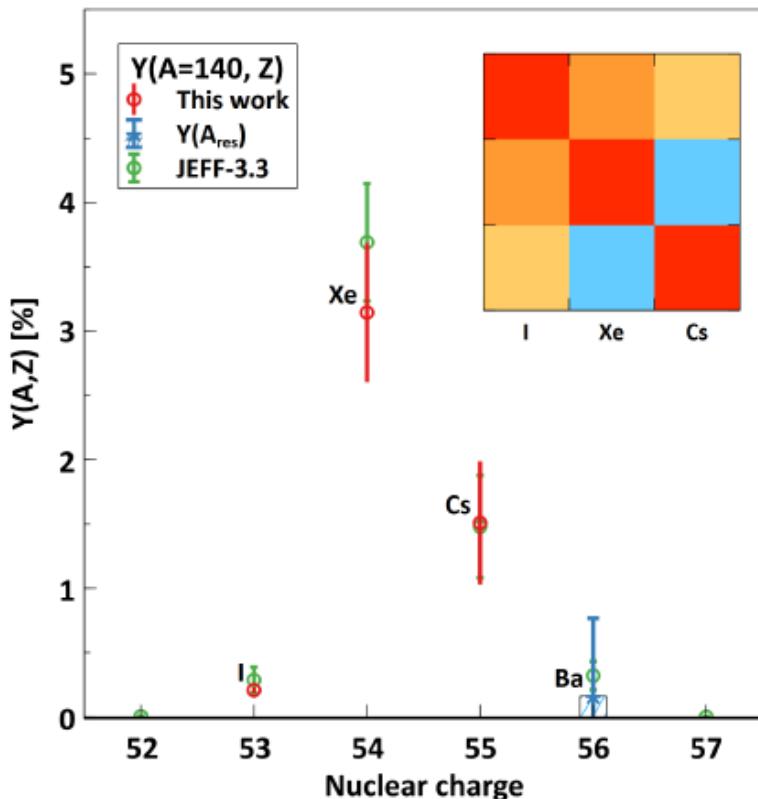


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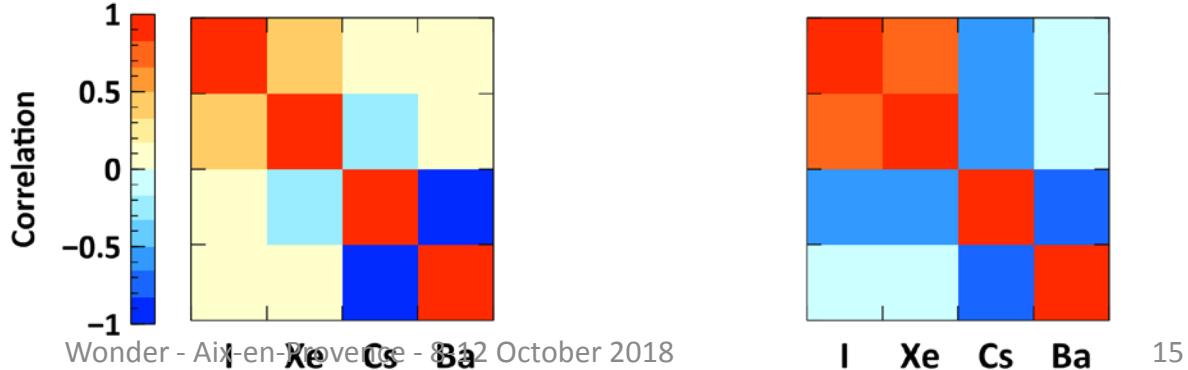
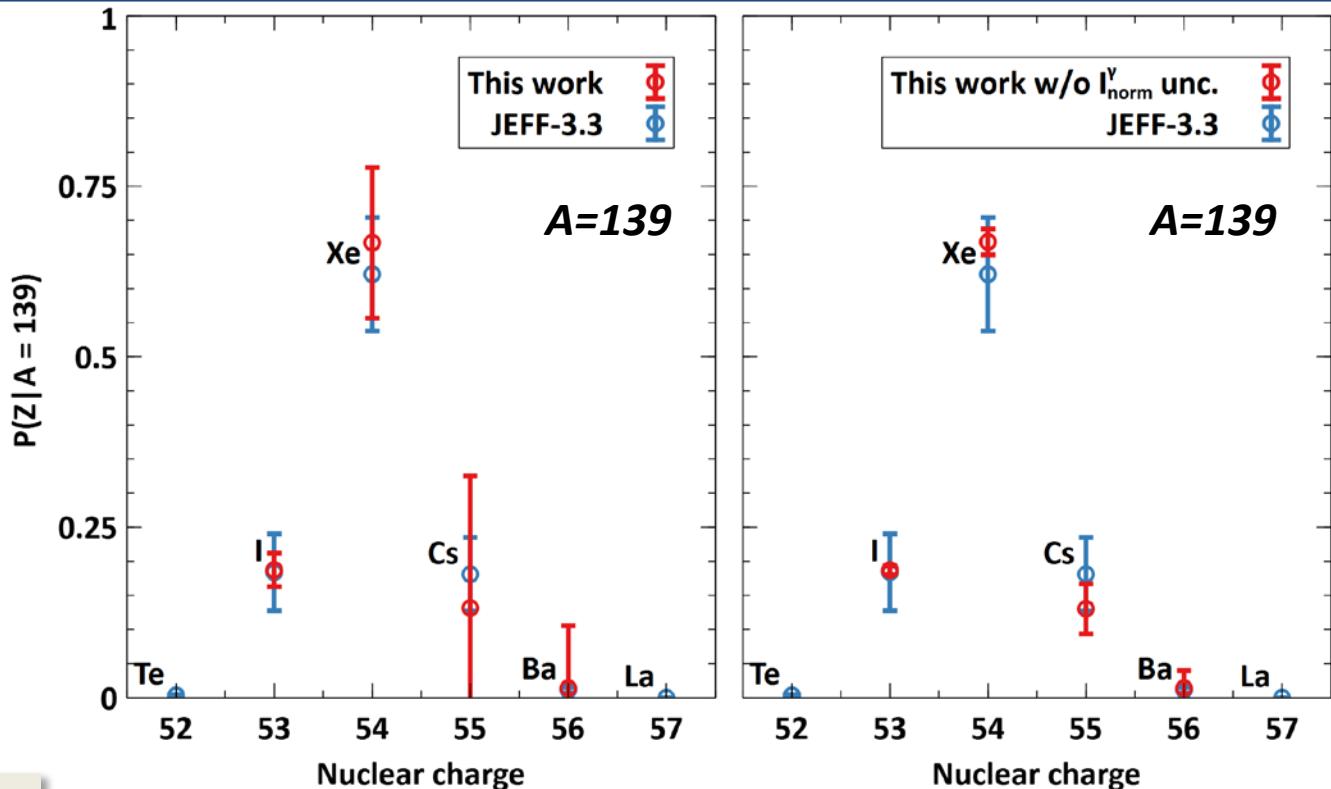
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$$I_{dec}^\gamma = I_{norm} \cdot I_{rel}^\lambda$$



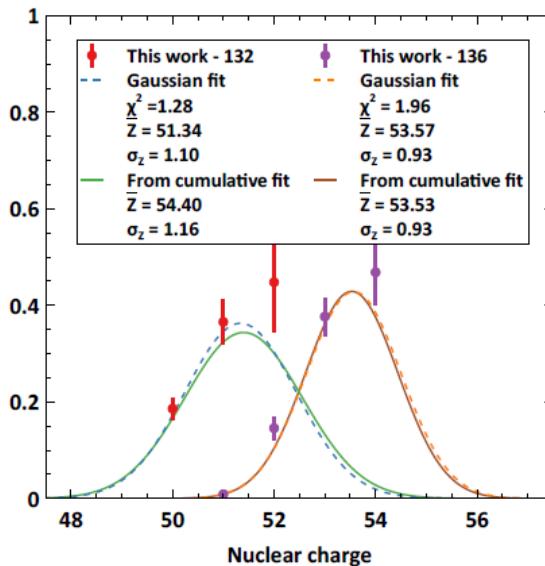
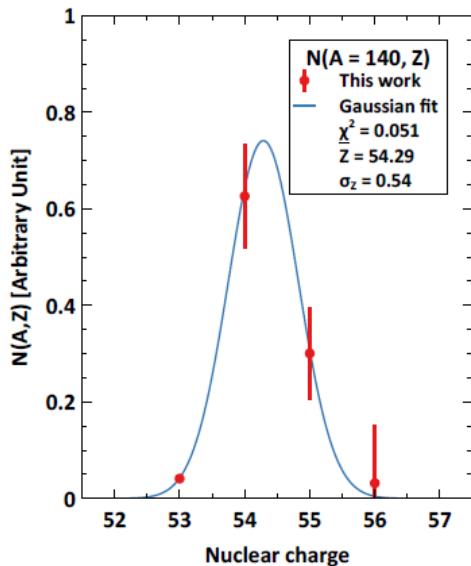
Systematic uncertainties per isotope  
→ Main contribution of total uncertainties and correlations



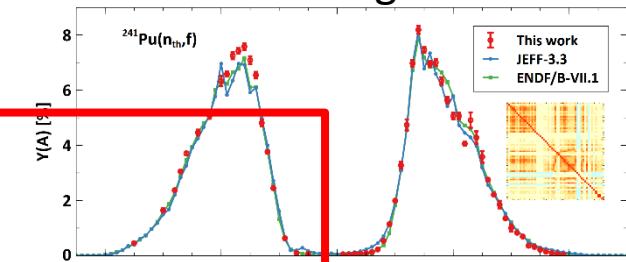
### 3.2- Indirect data : $^{241}\text{Pu}(n_{\text{th}}, f)$ nuclear charge polarization

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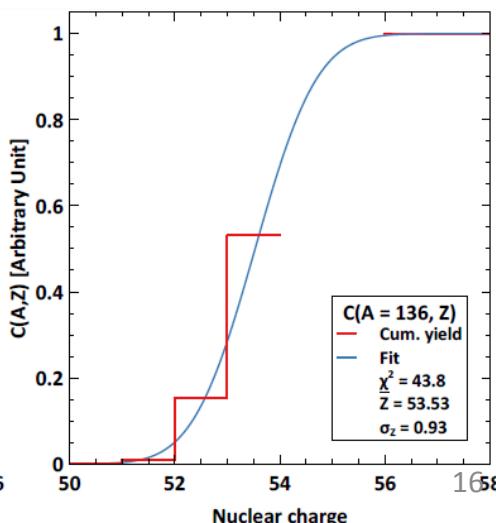
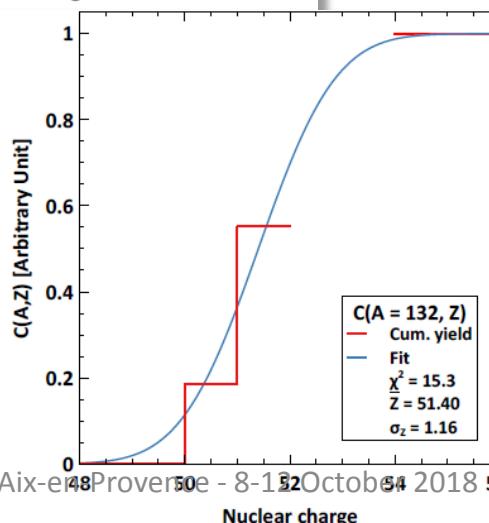
Complementarity of mass and isotopic measurement to cover all the isotopic range of a mass



$Y(A)$  measurement from Lohengrin

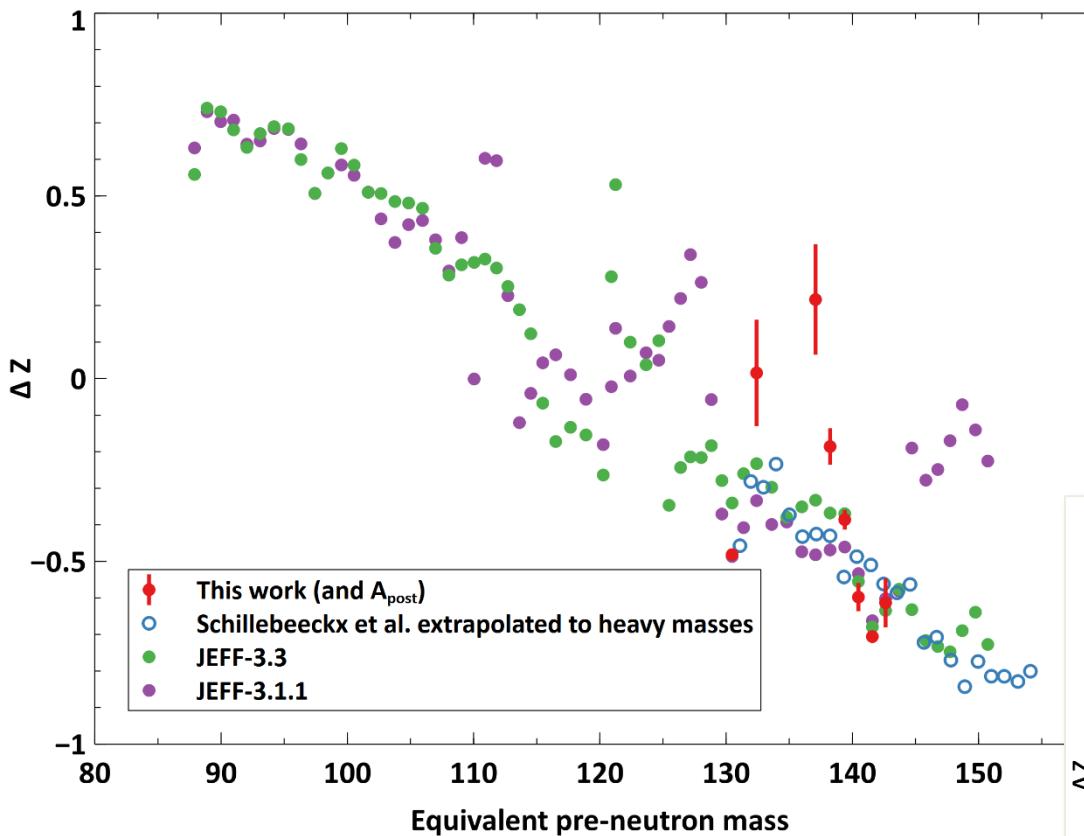


Constraint on  $P(Z)$



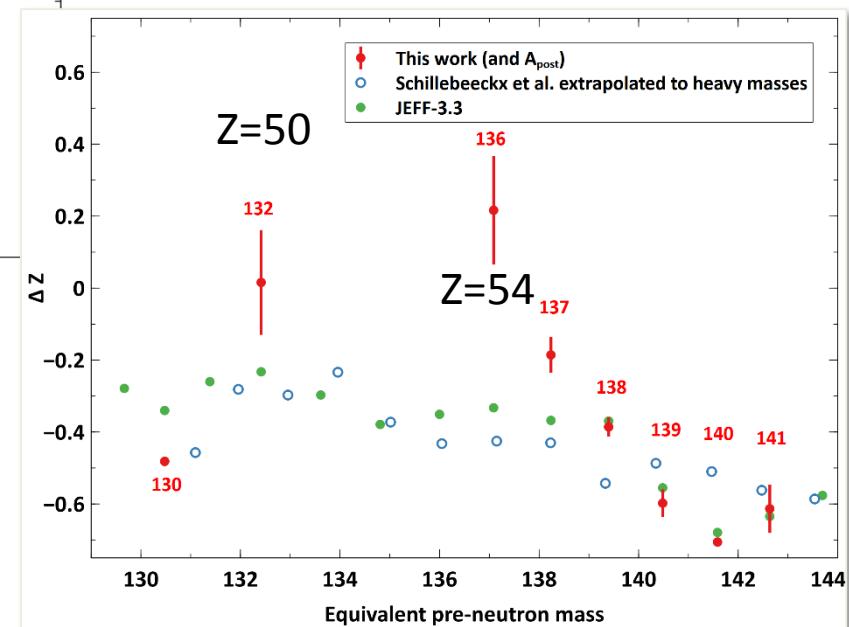
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Gaussian assumption used in analysis of current measurement and evaluation ?

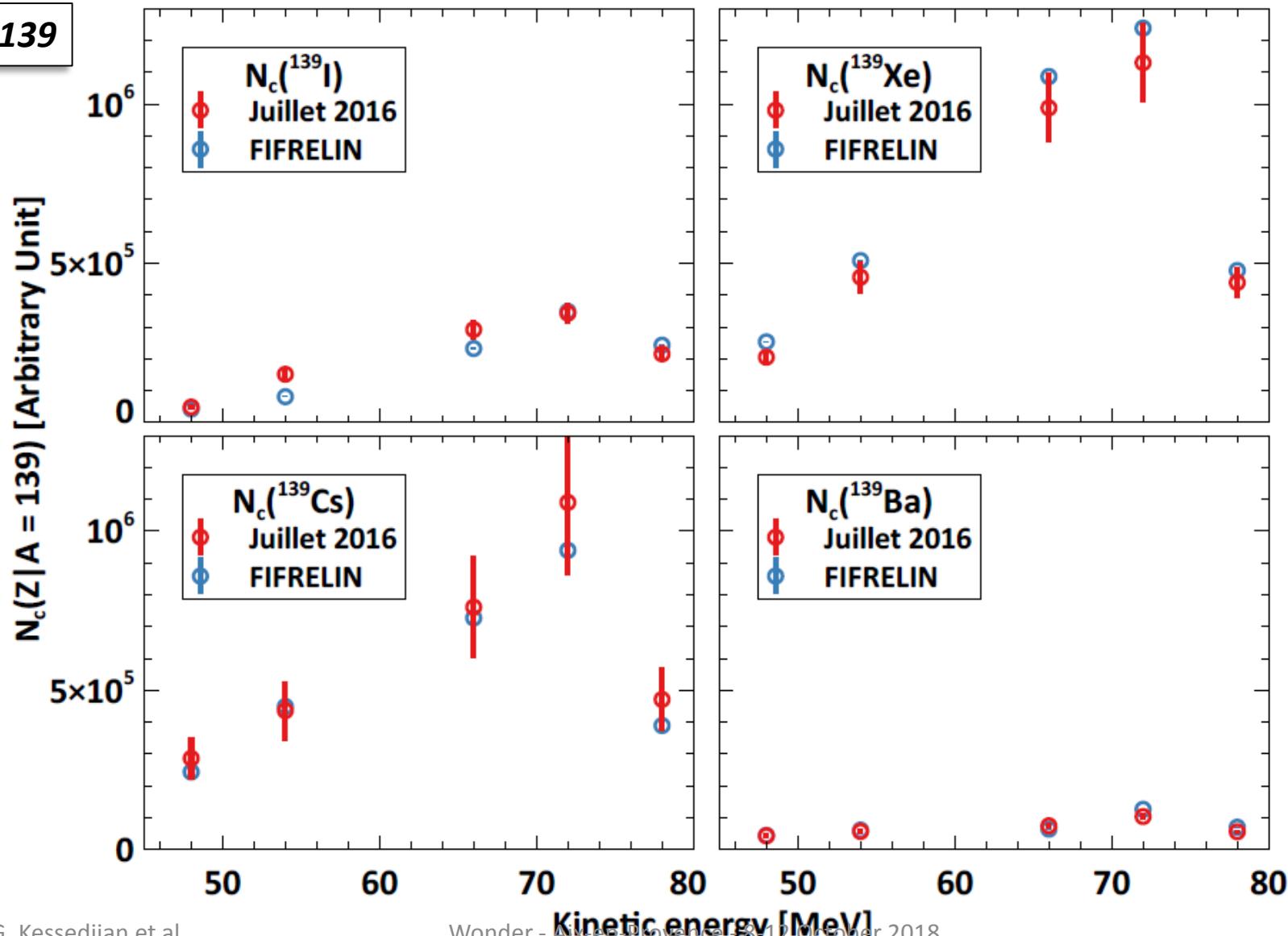
Needs of new measurements in the range [132-136]



### 3.3- Indirect data : Isotopic dependency with the kinetic energy and parity effect

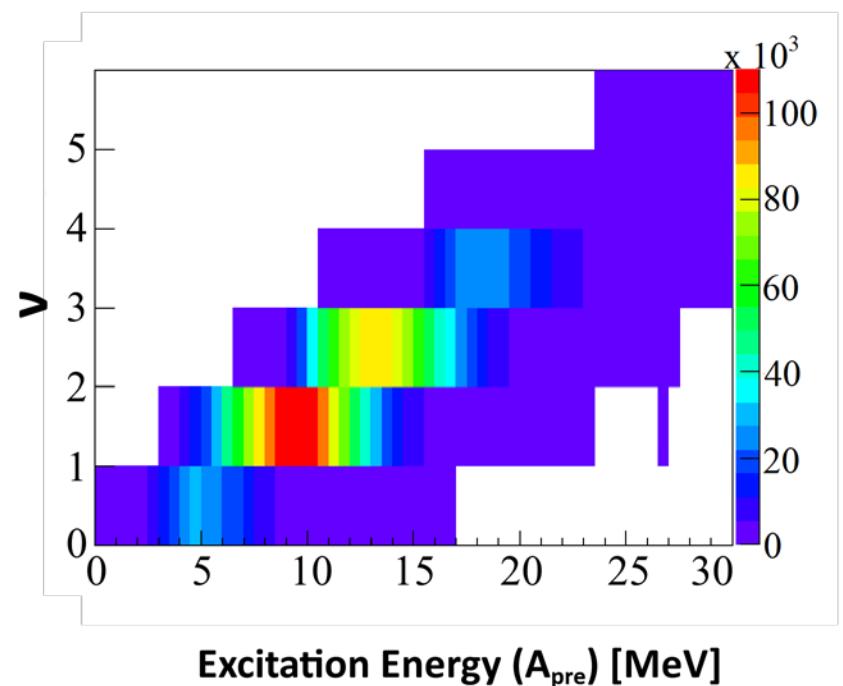
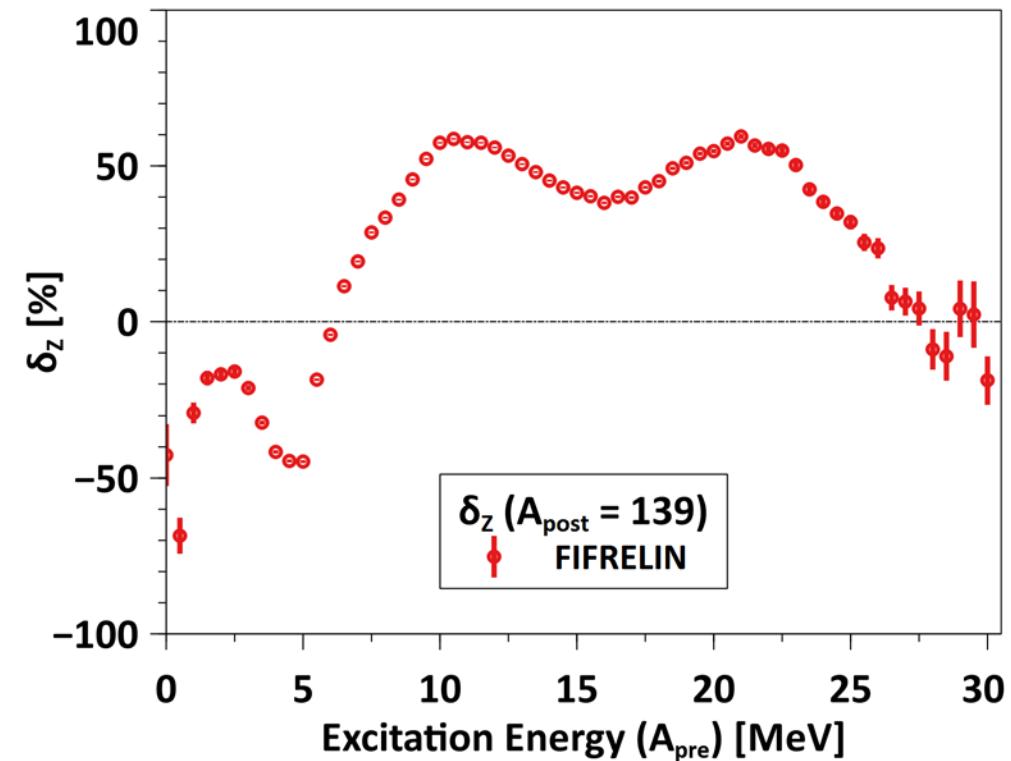
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**A=139**



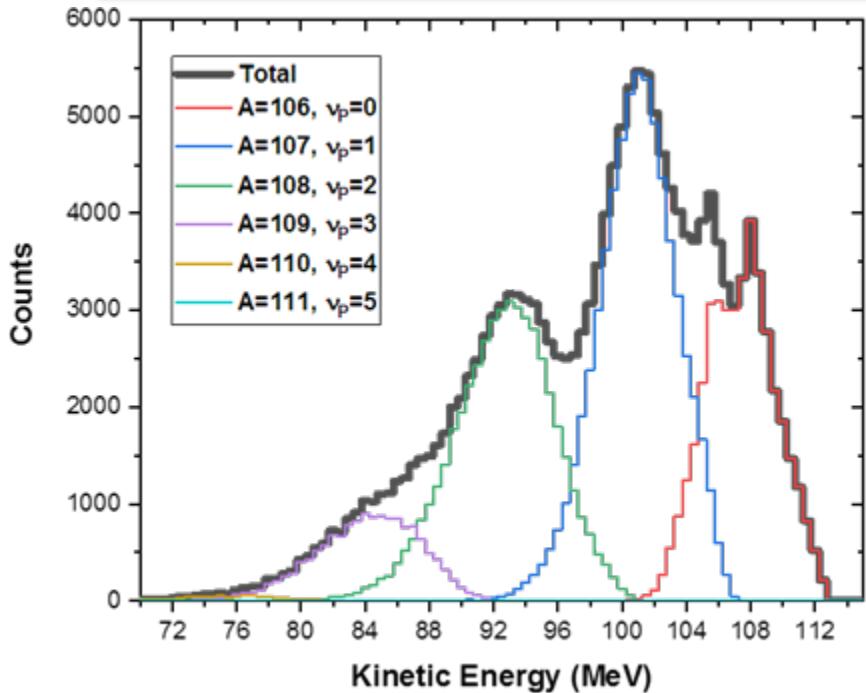
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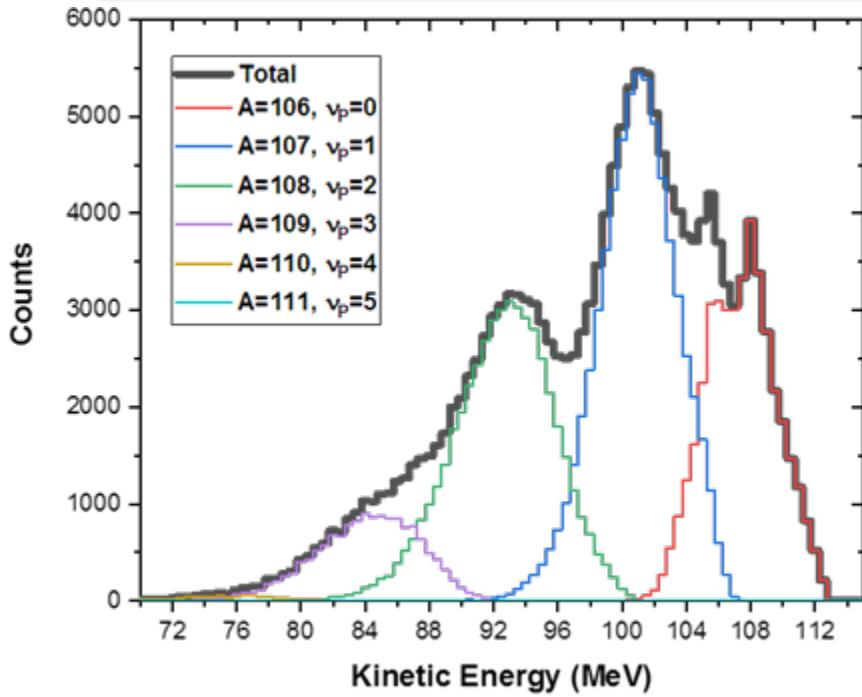
### 3.3- Indirect data : High resolution KE measurement → probe of n emission calculation

Post neutron emission KE distribution  
Fifrelin calculation

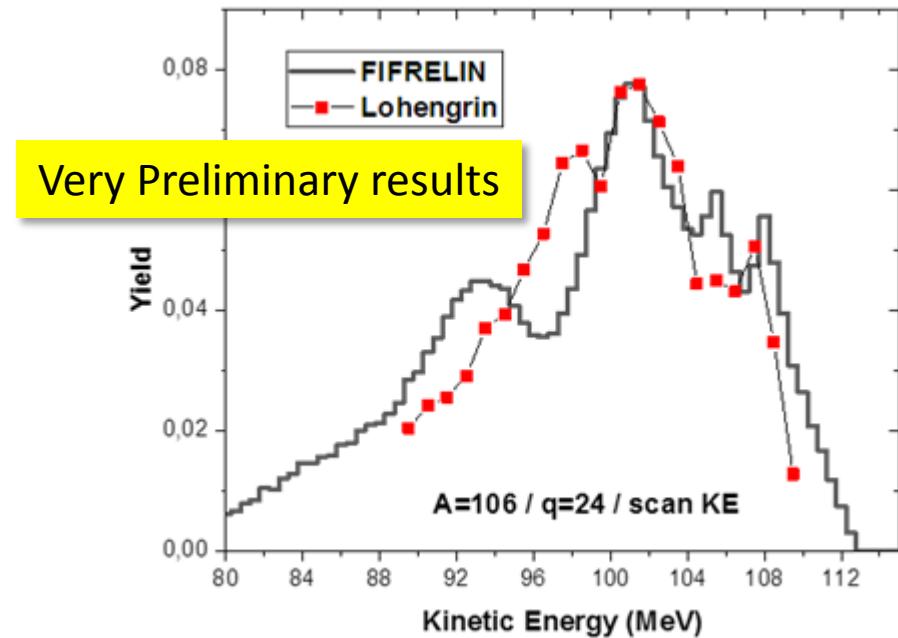


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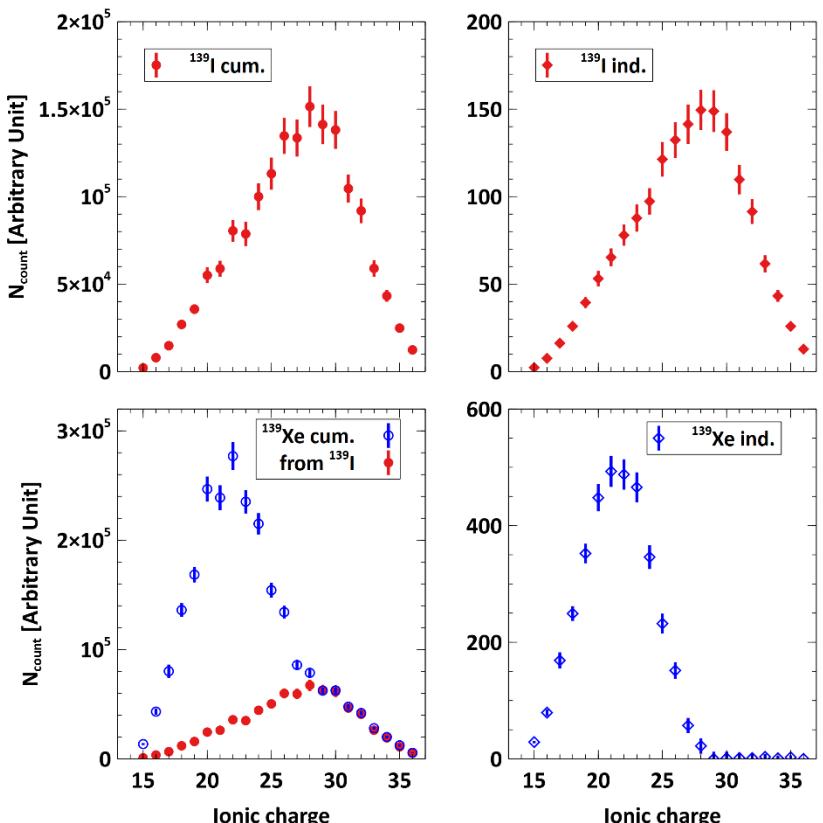


High resolution KE measurement with a very thin target without any couverture (target lifetime  $\sim 2$  days)



### 3.4- Indirect data : ns Converted Isomeric Ratio $\leftarrow P(q|A,Z)$

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Actinide target

Ni foil

X

$\gamma$

e<sup>-</sup>

Auger

Lohengrin

n<sub>d</sub>

Tape

clover Ge

clover Ge

Count rate

Ionic charge

Statistical ionic charge state  
Converted ionic charge state

$$IR = \frac{N(A, Z, m)}{N(A, Z, GS) + N(A, Z, m)}$$

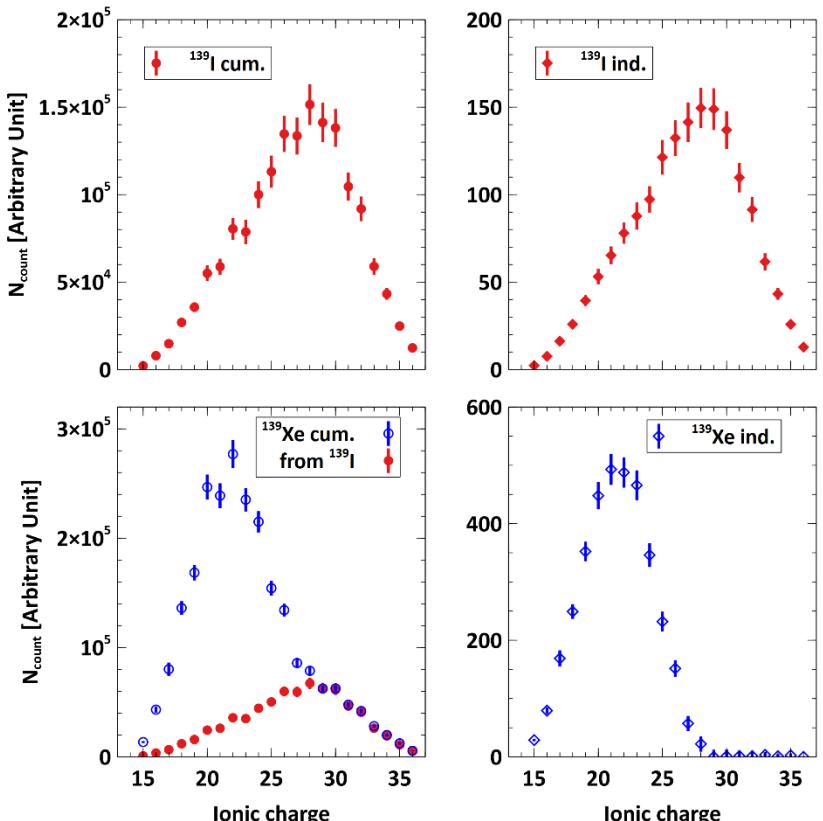


Shifted distribution

$$CIR = \frac{N(A, Z, m \rightarrow e^-)}{N(A, Z, GS) + N(A, Z, m \rightarrow \gamma) + N(A, Z, m \rightarrow e^-)}$$

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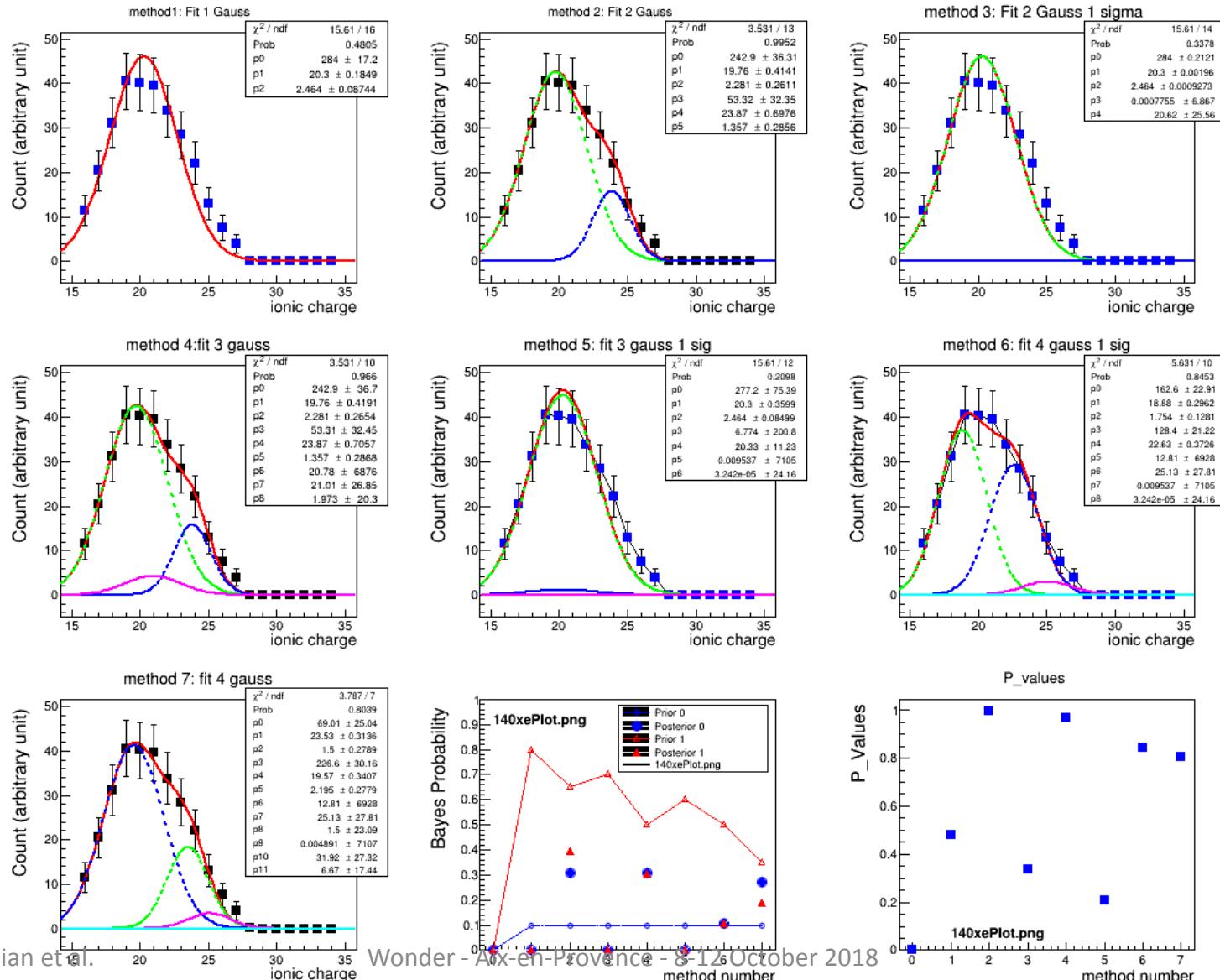
→ Shifted distribution

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Wonder - Aix-en-Provence q8\_12\_Betz October 2018

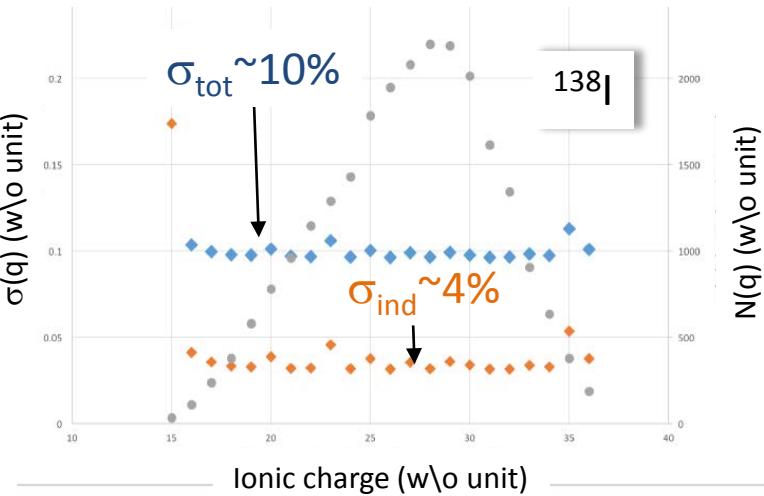
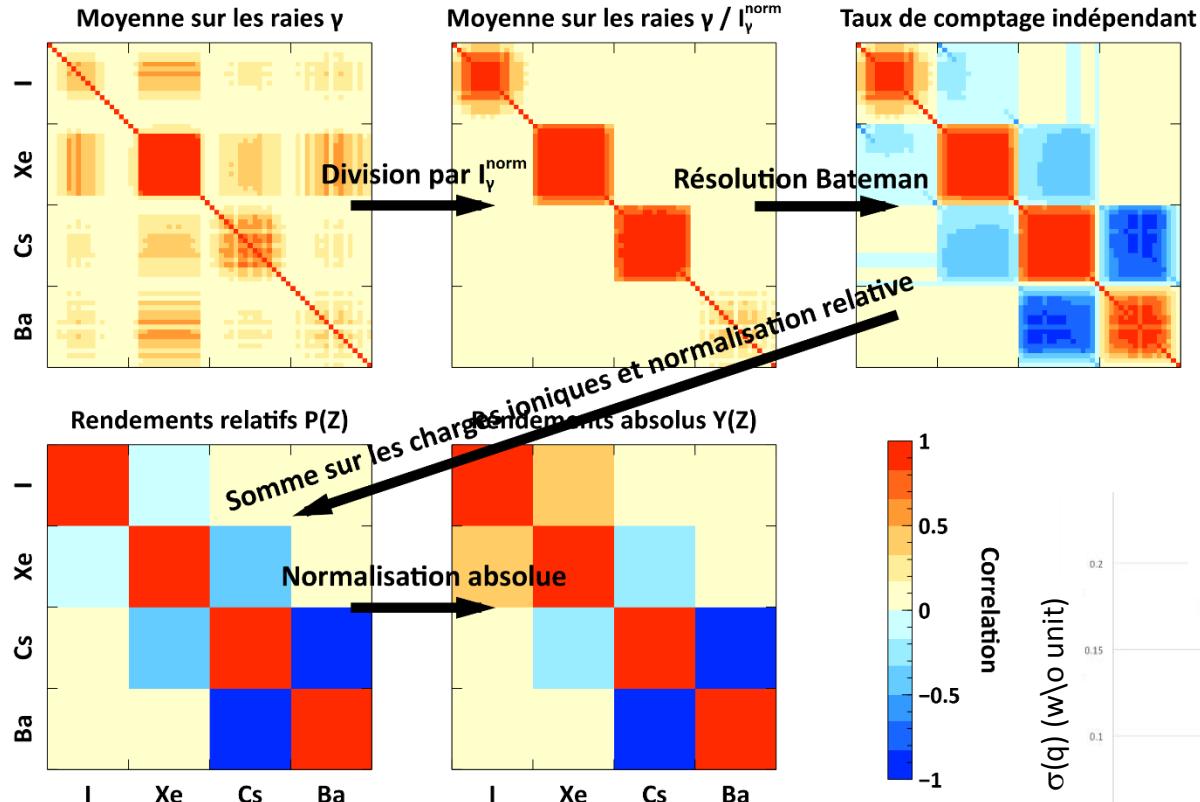
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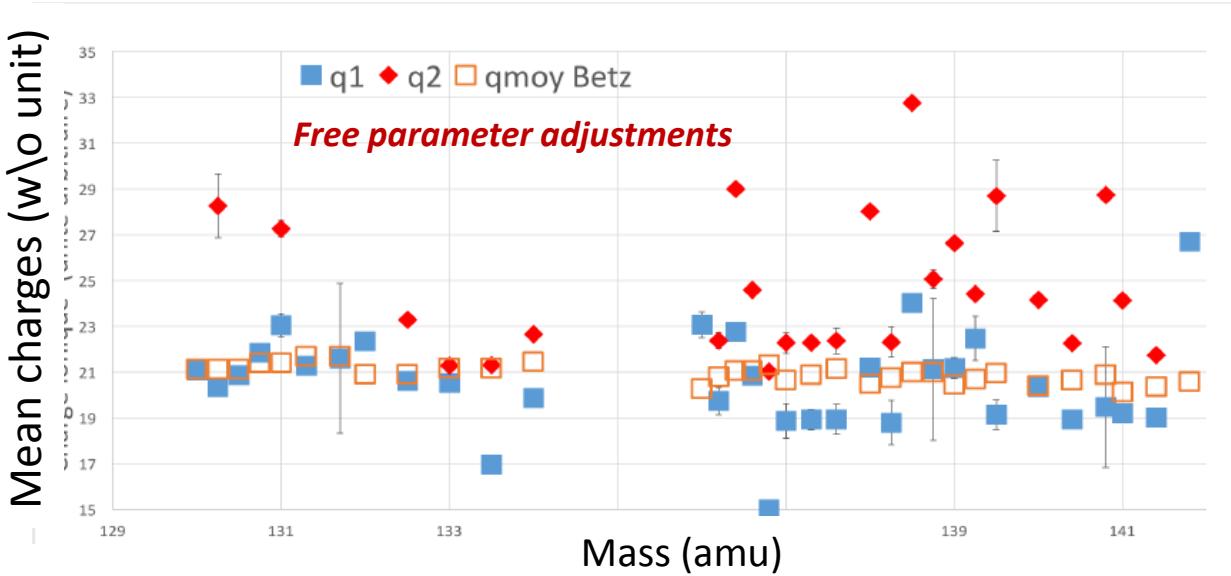
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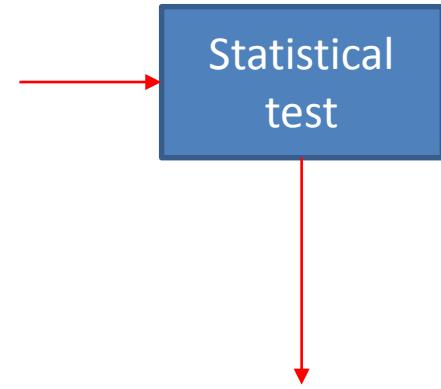


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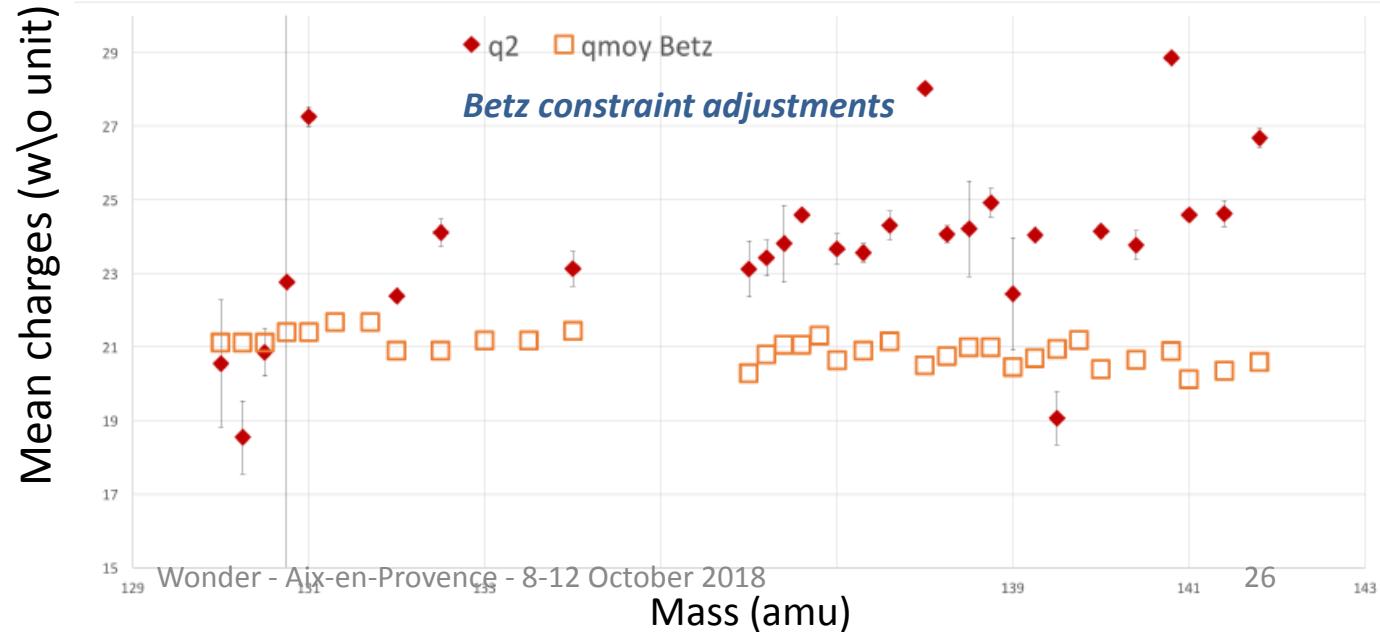
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Statistical test



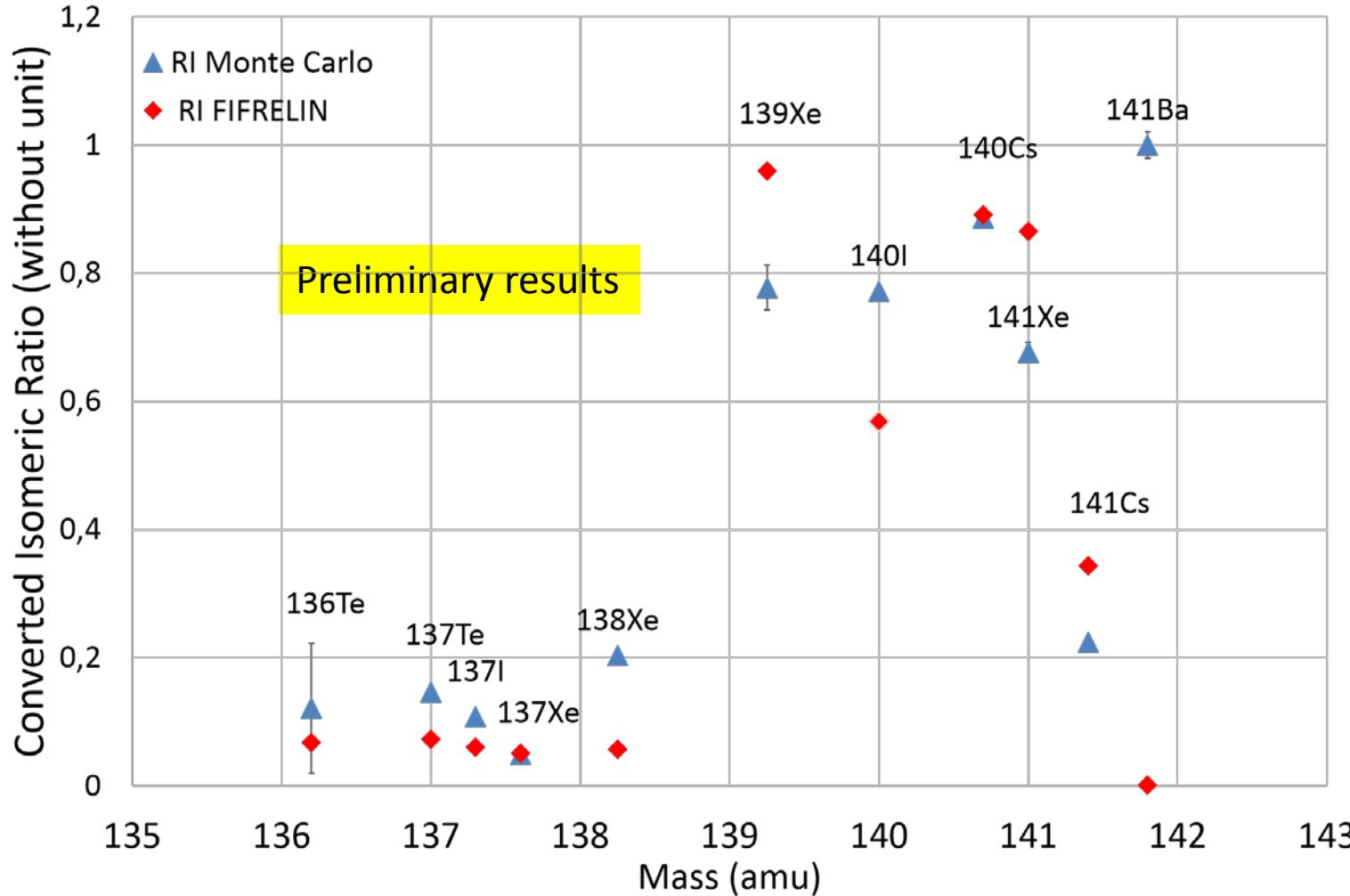
Preliminary results



### 3.4- Indirect data : ns Converted Isomeric Ratio $\leftarrow P(q|A,Z)$

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For deconvolution with P-Value >0,005 and  $\sigma_{CIR} < 30\%$  (with correlations)



# Conclusions & Perspectives

- **Direct data :** the experimental program is dedicated to precise measurements with a control of systematic uncertainties and an extraction of covariance matrix
  - $^{239}\text{Pu}(n_{\text{th}}, f)$  new measurement around the structures of the masses 134 and 141
  - $^{241}\text{Pu}(n_{\text{th}}, f)$  : complete measurement of the heavy peak in mass
  - $^{241}\text{Pu}(n_{\text{th}}, f)$  Isotopic and isomeric distribution of the masses 130, 132, 136, 137, 138, 139, 140, 141
- **Indirect data** is dedicated to test the phenomenological models and the assumptions used for the evaluations
  - Nuclear charge polarization
  - Isotopic and isomeric dependence with kinetic energy distribution
    - Parity and Neutron emission as a function of  $E^*$  (according to Fifrelin code)
  - Ionic charge distribution complete the base of Isomeric Ration (IR) measurement with the Converted Isomeric Ratios (CIR) which is now compared to Fifrefin calculations
- Continuation of the **experimental program** dedicated to observables **with the KE dependence** using the gamma emission in the framework of the test and validation of codes used in the evaluation
  - **less sensitives to nuclear structure data than absolute  $Y(A, Z)$**